(Unclassified)

The Role of Space Experiments in the Radiation Qualification of Electronic and Photonic Devices and Systems

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(Unclassified)

Outline

- Introduction
- Rational for doing a space experiment
- Limitations of space experiments
- Limitations of ground experiments
- Elements of a space experiment
- Results of previous space experiments

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Introduction

- Space experiments are occasionally launched to study the effects of radiation on electronic and photonic devices. This begs the following questions:
  - Are space experiments necessary?
  - Do the costs justify the benefits?
  - How does one judge success of space experiment?
  - What have we learned from past space experiments?
  - How does one design a space experiment?

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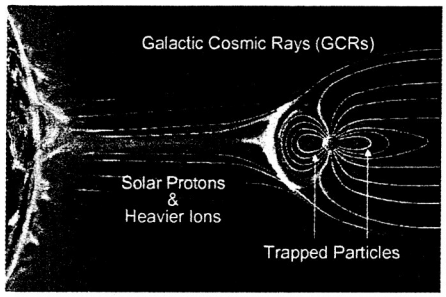
Space Radiation Environment

- Solar Particles
- Cosmic Rays
- Trapped Particles

Electrons
Protons
Heavy ions



Nikkei Science, Inc. of Japan, by K. Endo

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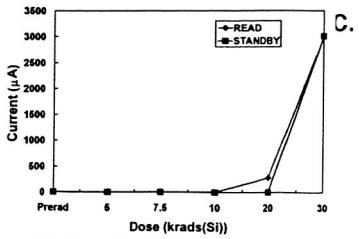
Radiation Damage

- Total Ionizing Dose:
  - ➢**Parametric degradation** – increased leakage currents, decreased speed, gain degradation.
  - ➢**Functional failure** – CMOS transistor's threshold voltage changes so the part cannot switch, too much supply current.
- TID Occurs in most devices – CMOS, bipolar, MEMS,



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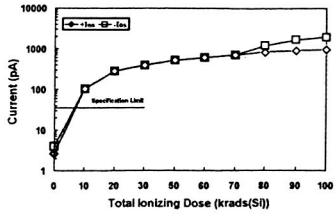

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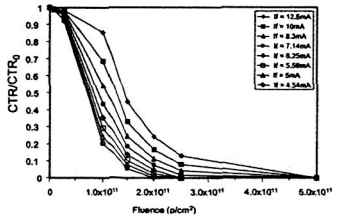
Radiation Damage

- Displacement Damage:
  - ➢ **Parametric degradation** – solar cell efficiency, bipolar gain, LED light emitting efficiency
  - ➢ **Functional failure** – solar cell efficiency drops below that needed for intended application, optocouplers fail to transmit data



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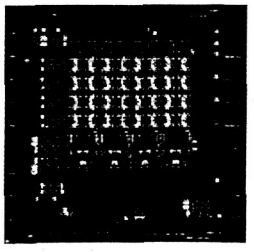
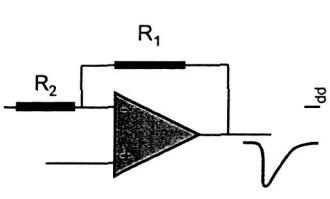
Radiation Damage

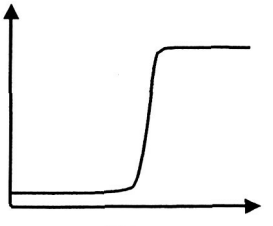
- Single Event Effects:
  - ➢ Non-destructive (SEU, SET)
  - ➢ Destructive (SEL, SEB, SEGR)



SEUs in SRAM



SETs in Linears



Latchup Current

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Radiation Damage Accounts for Some Anomalies/Failures

Chronology of satellite failures

Date	Satellite	Problem(s)
September 1997	PAS-6	Circuit failures in solar arrays
mid-May 1998	Echostar IV	One of two solar panels did not deploy
19 May 1998	Galaxy IV	Failure of primary and spare satellite control processor; total loss
13 June 1998	Galaxy VII	Temporary shutdown of some C-band capacity, failure of primary satellite control processor
24 June 1998	SOHO	Contact lost following a combination of ground control errors
June 1998 (?)	PAS-5	Partial loss of ability to recharge batteries
June 1998 (?)	Echostar III	Overheated electric power converters; several transponders lost
4 July 1998	DBS-1	Failure of primary satellite control processor
7 July 1998	GOES 9	Overheated momentum wheel; satellite replaced by GOES-10
mid-July 1998	Echostar IV	Loss of two transponders confirmed
Autumn 1998	Galaxy VIII-i	Partial loss of ability to recharge batteries
Autumn 1998	PAS-4	SCP failure
27 October 1998	GOES 8	Temporary loss of attitude control owing to Earth-sensor anomaly
24 November 1998	Palapa C1	Partial loss of ability to recharge batteries
6 December 1999	(Compton) GRO	Gyroscope failure; spacecraft later de-orbited for safety reasons
December 1998	TOMS	Single Event Upset disrupts spacecraft's computer operations, putting it into safehold mode
December 1998	PAS-8	Two of three Ku-band antennas not aligned properly
21 December 1998	SOHO	Safe mode, probably owing to loss of gyro

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Ground Testing Used to Qualify Parts for Space

- TID testing
  - Total Ionizing Dose:
    - Gamma rays (Co^{60}), X-rays
    - Co60 emits 1.17 and 1.33 MeV gamma ray. Rates on the order of 10 krad(Si) per hour.

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Ground Testing Used to Qualify Parts for Space

- DD testing
  - Proton (accelerator), neutron (accelerator or reactor)

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Ground Testing Used to Qualify Parts for Space

- Single Event Effects Testing
  - Accelerator, Cf 252, pulsed laser

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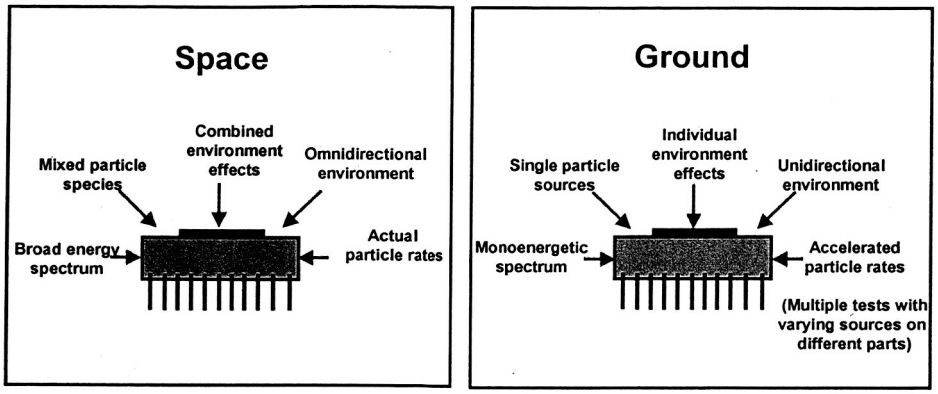
Testing Issues



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Modeling

- Models
  - Total Ionizing Dose & Displacement Damage Dose - SOLPRO, JPL, Xapsos/NASA
  - Single Event Effects - CREME96 (Protons & Heavier Ions), SPENVIS, GEANT
- Accuracy of models

(Unclassified)

Previous Successes

- What are the metrics of success?
  - Number of papers published
  - Parts used in later missions

(Unclassified)

Previous Successes

- MPTB
  - 56 papers published
  - Parts used in later missions
- CRRES
  - Papers published
  - Other information

(Unclassified)

Lessons Learned from Previous Space Experiments

- For best results assumed that testing needed to be done under identical conditions. This was found to be a problem with MPTB:
  - Identical boards, panel, software, telemetry. However, software was set for reading DRAMs in a way that was incompatible with ground testing due to higher rate on ground.
  - Starting telemetry took a long time. If a single error in typing occurred, had to reboot which took 11 minutes.
  - Data files gigantic as they contained telemetry information that was of no interest. Had to strip files.
  - Could not count the number of upsets unless check the data and that involved reboot of system.
  - Engineers unwilling to change software as no longer had funding.
- Need to find sponsors for data gathering and analysis.

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The Essentials for a Space Experiment

- Spacecraft needed
  - Proper orbit for what you want to study, don't start too early (5 yrs for parts),
- Environment monitors
  - P-FETs dosimeters
  - Particle telescopes CREDO
  - Bernie Blake's monitor
- Measure as much as possible
  - SEUs
  - Supply currents, leakage currents
  - Temperature
- Funding for data analysis and storage